

Article

Characterization of Fe₃O₄ Nanoparticles for Applications in Catalytic Activity in the Adsorption/Degradation of Methylene Blue and Esterification

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Abstract: The aim of this study is to evaluate the applicability of the catalytic activity (CA) of the Fe₃O₄ magnetic system in the adsorption/degradation of methylene blue and esterification. The thermal decomposition method allowed the preparation of Fe₃O₄ nanoparticles. The crystallites of the Fe₃O₄ structural phase present an acicular form confirmed by X-ray diffraction. Transmission electron microscopy results identified the acicular shape and agglomeration of the nanoparticles. Mössbauer spectroscopy showed that the spectrum is composed of five components at room temperature, a hyperfine magnetic field distribution (HMFD), two sextets, a doublet, and a singlet. The presence of the HMFD means that a particle size distribution is present. Fluorescence spectroscopy studied the CA of the nanoparticles with methylene blue and found adsorption/degradation properties of the dye. The catalytic activity of the nanoparticles was evaluated in the esterification reaction by comparing the results in the presence and absence of catalyst for the reaction with isobutanol and octanol, where it is observed that the selectivity for the products MIBP and MNOP is favored in the first three hours of reaction.

Keywords: Fe₃O₄ nanoparticles; catalytic activity; Mössbauer spectroscopy; methylene blue; esterification

1. Introduction

Iron oxides are widely distributed in nature and can be easily synthesized in the laboratory [1–5]. There are 16 iron oxides, one of the most common being magnetite (Fe₃O₄), and they can be present in their two aggregation states, as Fe⁺² and Fe⁺³ forming oxides [6–9]. Most iron oxides are crystalline. Physical and chemical properties depend on variables such as the degree of structural order and size of the crystal [7–10]. Magnetite is an iron oxide noted for its magnetic properties. Magnetite nanoparticles exhibit a large surface area that allows them to be functionalized to make biocompatible products (porous surface) [4–11]. This characteristic makes them especially suitable for a wide range of applications in diverse areas such as biotechnology, environmental, medical, pharmaceutical, catalysts, pigments, gas sensors, optical and electromagnetic devices, decontaminants, and wastewater treatment for dye removal [7–13]. In many chemical synthesis processes, the use of catalysts is necessary to carry out a specific reaction, so both conversion and selectivity are important criteria to evaluate the activity of a catalyst. Among the chemical reactions that use catalysts are esterification reactions where an ester and water are obtained from a carboxylic acid and an alcohol. The use of metal oxide